U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
A. C. TRUE, DIRECTOR.

ANNUAL REPORT OF THE PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1902.

BY

F. D. GARDNER,
Special Agent in Charge.

[Reprint from Annual Report of the Office of Experiment Stations for the year ended June 30, 1902.]

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ANNUAL REPORT OF THE PORTO RICO AGRICULTURAL EXPERIMENT STATION FOR 1902.

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INTRODUCTION.

This, the second annual report of the Porto Rico Agricultural Experiment Station, presents the present status of the station and gives in general terms the progress and results of the principal lines of work for the year which has elapsed since the first annual report was made. The first report was printed as part of the Annual Report of the Office of Experiment Stations, and also issued as a separate or reprint of the same. At the time of its preparation the station had not secured a site for a permanent location, and in view of the probable delay in securing a suitable site arrangements had been made and work commenced in carrying out a temporary series of field experiments at Rio Piedras, near the capital. This work was vigorously pushed for several months, but the grounds and experiments were abandoned in August of the present year and the station moved to its permanent quarters at Mayaguez.

The United States Congress made an appropriation of $12,000 for carrying on the work for the present fiscal year. The insular legislature came to the aid of the station and appropriated $15,000 for the purchase of land, while the municipality of Mayaguez donated $4,000 additional for this same purpose, thus making the total income for the station for the present fiscal year $31,000.

The soil survey, which was undertaken in cooperation with the Bureau of Soils in January, 1902, has been completed, and the resulting maps and manuscript are ready for the printer. This will first be issued by the Bureau of Soils in its annual report, after which it will be translated into Spanish for the use of the experiment station.

The station staff, which at the time of the last report numbered only three, has now been increased to five, the two additions being a coffee expert and a clerk and stenographer.

PERMANENT LOCATION.

The need of a suitable tract of land on which to permanently establish the agricultural experiment station was presented to the insular

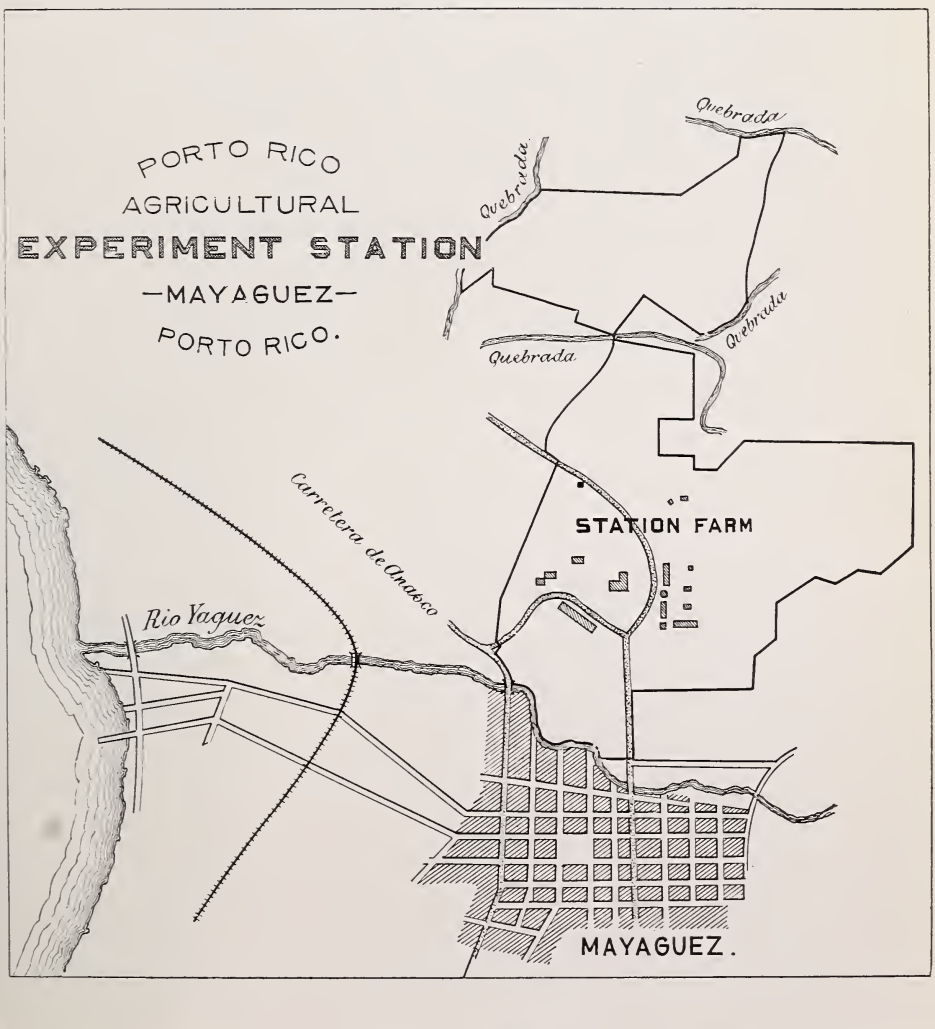
legislature in February, 1902, and the bill making immediately available $15,000 for the purchase of such a site passed both houses with very little opposition. Bids were called for in March, which were to be opened the 12th of May. On the latter date, Dr. Walter H. Evans, of the Office of Experiment Stations, who had been authorized by the Secretary of Agriculture to proceed to Porto Rico and act with the representative in charge of the station, conferred with the governor and the secretary of the interior of the island with reference to selecting a site as offered by the bids.

Twenty-three proposals were received in proper form, and those that were obviously best were visited by the committee and examined with reference to their suitability for the purpose, the result being the selection of a site adjacent to the city of Mayaguez. This proposal had been submitted by the city itself, it having secured an option on a tract of land for $19,000, the excess over the appropriation to be paid by the city. Possession of the land was given the last week in June, and the experiment station removed from Rio Piedras to its new site the first week in September.

DESCRIPTION OF FARM.

The farm, embracing 235 acres, formerly known as "La Carmen," is located near the city of Mayaguez. A portion of the river-bottom land borders the river Yaguez and the main road to Anasco. The map (Pl. XXVIII) shows its form and location with reference to the city and the "playa." The land is diversified in character of soil, topography, and exposure. There are about 35 acres of river-bottom land (Pl. XXIX, fig. 1) nearest the city, which contain a deep loam, to the depth of 3 feet or more. This, at present, is all in "malojilla" grass. The land to the north of this consists of low, rounded hills and intervening valleys and coves (Pl. XXIX, fig. 2), many of which are well sheltered and well watered. In various sheltered places coffee is planted, there being in the aggregate about 7 acres planted to that crop; the remainder of the land is largely in an unproductive condition, being overgrown with weeds, bushes, and small trees, intermingled with a small amount of various kinds of grasses, which would furnish some pasture. Although in an unproductive condition, the place presents very good possibilities and is well suited to the purpose of the experiment station.

The main residence, a frame house of 11 rooms, has been put in repair, painted both inside and out, and is occupied as living quarters (Pl. XXX, fig. 1). An old masonry sugar building, a large part of which was unroofed, and the walls of which were more or less broken and damaged, has been repaired, roofed, and painted both inside and out, and will serve the present needs of the station for office, laboratory, and working quarters (Pl. XXX, fig. 2). There is a brick factory



PORTO RICO STATION—MAP SHOWING LOCATION OF THE STATION.

FIG. 1.—PORTO RICO STATION—RIVER BOTTOM LAND AND PART OF MAYAGUEZ, AS SEEN FROM THE STATION RESIDENCE.

FIG. 2.—PORTO RICO STATION—BOTTOM LAND, PRINCIPAL BUILDINGS, AND UPLAND BEYOND, AS SEEN FROM AÑASCO ROAD BRIDGE AT THE RIVER YAGUEZ.

FIG. 1.—PORTO RICO STATION—STATION RESIDENCE.

FIG. 2.—PORTO RICO STATION—OFFICE, LABORATORY, AND STORAGE QUARTERS.

containing three kilns and several drying sheds, also numerous small huts for the use of the laborers on the farm.

To fully equip the station with suitable buildings and put the farm in the best condition for effective work, funds in addition to those granted by the National Government will be required, and it is therefore hoped that the insular government will continue its liberal policy toward the station.

EQUIPMENT.

A fair equipment has already been collected for the use of the station in the way of work animals, wagons, plows, harrows, and other machinery; also a good supply of small implements, such as shovels, forks, hoes, rakes, scythes, machetes, etc. A small amount of apparatus for spraying purposes and for the pruning of trees has been secured; also various chemicals and insecticides.

The office is provided with a fair amount of furniture in the way of desks, chairs, and bookcases, together with the smaller furniture which goes with them. A library has been commenced, and about 200 bound volumes are now on its shelves, with a considerably larger number of unbound publications. An exchange list has been organized with a number of leading agricultural periodicals, not only in the United States, but in foreign countries as well, and upward of twenty different periodicals are now on the files of the station. A collection of economic plants and insects has been commenced under the direction of the entomologist and botanist. With sufficient means at our command, it is only a matter of time when this equipment can be made a most valuable one to the people of Porto Rico.

The clearing of a portion of the land for the planting of crops has been commenced, and plants and seeds of different kinds are being secured, not only from different sources at home, but also from foreign countries and neighboring islands.

SOIL SURVEY.

The soil survey conducted in cooperation with the Bureau of Soils of the United States Department of Agriculture, which was spoken of in the first report, was commenced in January and completed in April of the present year. The Bureau of Soils furnished three experts during this time to carry on the field work, and also bore the larger part of the field and traveling expenses.

The area surveyed comprises a strip 10 miles in width, extending from the north shore at Arecibo in a north and south direction along the line of the military road to the south shore at Ponce. It embraces 360 square miles, or about 220,000 acres, which is equivalent to one-tenth of the island. In crossing the island it cuts all the principal geological formations, which extend for the most part in an easterly

and westerly direction, and it also extends into districts of maximum climatic differences. This survey, therefore, includes nearly all of the soil and climatic conditions to be found on the island.

On account of the very rugged character of much of the district, the lack of any topographic maps, and, in fact, the lack of a geographic map which was accurate, the work proved to be most difficult. All roads, trails, and streams had to be traversed and a base map made on which to map the soils. Much credit is due the field party for the satisfactory way in which the work was executed.

The work consisted in a classification of the soils of the area and mapping of each type on the scale of 1 mile to the inch; a study of the agricultural practices and possibilities, together with the best adaptation of each type to crops. Typical samples of soil and subsoil were taken from each type for physical and chemical study in the laboratory. The report and map resulting from this survey have been prepared and are ready for the press. They will first be printed as a part of the annual report of the Bureau of Soils. It is proposed to have a translation of the report printed in Spanish and issued at the same time by the station for distribution to the people on the island, together with an extra edition of the maps that may be secured from the Bureau of Soils. This promises to be of considerable economic importance, and it is hoped that the cooperative work can be continued year by year until the whole island has been surveyed.

COFFEE INVESTIGATIONS

For many years coffee has been the most important crop of the island. In acreage it far exceeds that of any other crop, and its export value has usually exceeded that of all other exports combined. The census of 1899 gave the acreage in coffee as 197,031. The damage caused by the hurricane of that year, together with the great increase in the world's supply of coffee and the fact that Spain, in giving up possession of the island, increased her tariff on Porto Rican coffee to about 8½ cents per pound, are conditions which have prevented any increase in the acreage of coffee. These adverse conditions make it all the more necessary that the experiment station should do what it can to support the chief agricultural industry of the island, and experiments with coffee are, therefore, taking a prominent place in the station work.

Seed coffee, which was gathered a year ago, has been planted in seed beds especially prepared for the purpose. This preparation consisted in plowing and pulverizing the soil, then elevating it into beds 3 by 15 feet in area, and surrounding each with planks to prevent caving. Straw-covered sheds were then constructed to protect the beds from direct sunlight and from heavy rains. (Pl. XXXII, fig. 4.) During the month of January, 1902, the seeds were planted in the beds, 2

FIG. 1.—PORTO RICO STATION—MAGUEY (FURCRÆA GIGANTEA) IN FLOWER.

FIG. 2.—PORTO RICO STATION—MAGUEY (FURCRÆA GIGANTEA).

FIG. 1.—PORTO RICO STATION—BANANAS, STATION GROUNDS AT RIO PIEDRAS.

FIG. 3.—PORTO RICO STATION—EXPERIMENTAL TOMATO PLAT RESULTS OF A BACTERIAL DISEASE.

FIG. 2.—PORTO RICO STATION—KAFIR CORN AND NATIVE CORN.

FIG. 4.—PORTO RICO STATION—COFFEE SEED BEDS.

inches apart each way, there being approximately 1,600 seeds in each bed, the total number of beds being 20. In from six to seven weeks the seeds germinated, and resulted, a few weeks later, in a good stand of healthy plants. Eighty additional beds, similar in every respect to those planted, also provided with straw roofs, were then constructed for nursery beds. When the small plants had fully developed their second pair of leaves they were transferred from the seed beds to the nursery beds in order to give them more room to develop. During this transferring process another selection was made by rejecting all inferior plants, or those having poorly developed root systems. In the nursery beds the plants were set 6 by 6 inches apart, there being 100 beds. Fertilizers of different kinds and different amounts were applied to these in order to accelerate the plant growth, as well as to ascertain the kind of fertilizer best suited to this purpose.

Arrangements have been made to carry on experiments with reference to the improvement of an old coffee grove on the estate known as "La Carmelita," situated about 8 miles north of Ponce, operated by the "La Carmelita" company. Ten acres have been divided into as many plats, from which the present crop is being harvested and the yield of each plat ascertained. After the crop has been gathered each plat will be treated in a different way, some being thinned and pruned, others having the plants cut off a few inches above the ground in order to obtain thereby a new growth. Some will be given cultivation, while others will have the shade reduced, etc.

Twenty-five acres of virgin forest land has also been arranged for, and a part of it will be cleared and planted with the new plants from the nursery. Different varieties of coffee are also being secured from different coffee-producing countries, in order to ascertain what varieties may be best suited to the conditions of Porto Rico, as well as to give an opportunity for cross-breeding, budding, etc., which will be important factors in coffee improvement.

TEMPORARY EXPERIMENTS AT RIO PIEDRAS.

The field experiments conducted at Rio Piedras, near the capital, were necessarily of a temporary nature, for the reason that it was desirable to secure a permanent site and have the station located, in order that experiments of a permanent character could be taken up at the earliest possible date. Arrangements were accordingly made for this purpose by the leasing of a building for office, laboratory, and living quarters, and also 30 acres of land, a part of which was cleared of weeds and brush, the drainage system improved, and the soil prepared for crops.

Planting began early in November and was continued at frequent intervals until June, 1902. The different plantings were made in order

to ascertain, if possible, the best season of the year in which to plant, or, in other cases, because the seeds for planting had not been previously secured. Some of the plantings were also made in order to test different kinds of commercial fertilizers, and others to experiment with different methods of cultivation. Repetitions in the plantings were necessary, because the plants were either destroyed by "changa" or the seeds were eaten up by ants or field mice.

The season was abnormal; November, December, and January were unusually wet, the total rainfall for the three months being 23.89 inches. During these three months there were only seventeen days on which no rain fell. At the close of January dry weather set in, and during the month of February the total rainfall was less than one-half inch, while for March it was only 2.19 inches. This very dry spell, with high trade winds from the east, lasted until the middle of April, when rains again set in, and during May and June the total rainfall was 21.53 inches.

The table below shows the various classes of crops planted and gives, in condensed form, the number of varieties of each, the number of plantings, and the character of the experiment, together with the results and a few miscellaneous notes. The fact that many of these products have proven failures does not mean that they can not be successfully grown on the island. The time has been too short and the conditions during that time too unfavorable to draw from them many definite conclusions. Many of the crops that have failed entirely might have succeeded fairly well if planted on better soil, subjected to more normal weather conditions, and left undisturbed by insects and diseases. The most important points brought out by these experiments were the impoverished condition of the soil and the necessity of meeting it with some rational system of manuring; the need of remedial measures for combating insect enemies and plant diseases, and the fact that tropical conditions are unfavorable to the growing of many of the northern truck crops.

Mention will here be made only of some of the more important crops or of those that have received most attention:

Summary of experiments with various crops at Rio Piedras.

VEGETABLE AND GARDEN CROPS.

Name of product.	Number of varieties tried.	Number of plantings made.	Character of experiment.	Result.	Miscellaneous notes.
Artichoke	1	1	Adaptation	Failure	Failed to sprout.
Arrowroot	1	1	do	Fair	Not matured.[a]
Asparagus	1	3	do	do	
Beans	9	9	do	Failure	Leaf hopper great enemy.
Beets	7	6	do	Fair	
Cabbage	3	3	do	do	
Canna, edible	1	1	do	Excellent	

[a] The tropical vegetables require a long time to come to maturity and these were not ready to gather when the station was removed from the Rio Piedras grounds.

Summary of experiments with various crops at Rio Piedras—Continued.

VEGETABLE AND GARDEN CROPS—Continued.

Name of product.	Number of varieties tried.	Number of plantings made.	Character of experiment.	Result.	Miscellaneous notes.
Cantaloupe	1	1	Adaptation	Failure	Eaten by changa.
Carrot	1	1	do	Fair	
Cauliflower	1	1	do	Failure	
Castor bean	1	1	do	Good	Not matured.[a]
Celery	1	1	do	Failure	
Corn, sweet	11	8	do	do	
Cucumber	6	8	do	do	
Dioscorea	2	2	do	Fair	
Eggplant	2	2	do	do	
Gumbo	3	3	do	do	Suffered from plant lice.
Ginger	1	3	do	do	
Hedionda	1	1	do	do	
Lettuce	5	6	do	do	
Luffa	1	1	do	Failure	Did not sprout.
Malanga	1	1	do	Poor	Soil too dry.
Muskmelon	5	6	do	Failure	
Onion	4	6	do	Fair	Some plantings failed.
Parsnips	2	3	do	do	
Parsley	2	3	do	do	
Peas	5	4	do	Poor	Matured too early.
Peanuts	1	2	do	do	Injured by mice and spot fungus.
Peppers	3	1	do	Failure	
Potatoes:					
Sweet	5	14	Fertilizers	Fair to excellent.	Yields 1 to 10 tons per acre.
Irish	1	3	Adaptation	Failure	Destroyed by root rot.
Radishes	6	5	do	Fair to good	
Sechium	1	1	do	Failure	
Spinach	2	3	do	do	
Squash	4	7	do	Fair	Mice ate seeds.
Tomatoes	3	4	Adaptation and disease.	Failure	Destroyed by bacterial disease.
Turnip	2	4	Adaptation	Poor to fair	
Watermelon	7	8	do	Fair	
Yam	1	1	do	do	
Yautia	6	8	do	do	Not matured.[a]
Yuca	4	8	do	Poor to good	Do.

FLOWERING BULBS.

Amaryllis	1	1	Comparison	Good	Common on island.
Freesia	1	2	Adaptation	Failure	
Hyacinths	1	1	do	Poor	
Lilies	3	22	do	Fair	
Narcissus	1	3	do	do	

FIELD AND FORAGE CROPS.

Barley	1	1	Adaptation	Failure	
Blue grass	1	2	do	Fair	
Clover:					
Alfalfa	1	2	do	do	
Alsike	1	1	do	Failure	
Common red	1	2	do	do	
Crimson	1	1	do	do	
Corn:					
Dent	1	2	do	Poor	
Native flint	1	1	do	Fair to good	
Kafir	1	2	do	do	
Cotton	1	2	do	Fair	
Cowpeas	6	3	do	Poor	Leaf hopper a great enemy.
Malojilla grass	1	1	Forage	Good	
Millet	1	1	Adaptation	Failure	
Oats	1	2	do	Poor	Forage, but no seed.
Peas, Canada field	1	1	do	Fair	
Rye	1	1	do	Failure	
Teosinte	1	1	do	Good	
Tobacco	1	1	do	Failure	Seed failed to sprout.

[a] The tropical vegetables require a long time to come to maturity and these were not ready to gather when the station was removed from the Rio Piedras grounds.

VEGETABLE AND GARDEN CROPS.

Beans.—Nine varieties were planted, as follows: Early Market, Wardwell Kidney Wax; Challenge Pole; Perennial Climbing; Stringless Green Pod; a Kansas variety, no name; Refugee; Improved Golden Wax, and Early Red Palestine.

The two varieties first named were planted November 23 and 27, respectively. They came up and grew well for a short time, but were destroyed by a fungus which attacked the base of the stem and part of the root system. The variety Challenge Pole was planted December 26, and in August, about eight months later, the vines had made a fair growth and were filled with blossoms. They had also matured a few pods and were not much bothered by insects. Perennial Climbing failed to germinate. The next two named varieties, planted in January and February, were destroyed by leaf hoppers, as were also the varieties Refugee and Improved Golden Wax, which were planted in May and June, respectively.

In May several of the above-named varieties were again planted, but the leaf hopper at this time was so prevalent that very few of the plants survived.

Beets.—Seven varieties were planted in six different plantings. Several of these plantings did fairly well, and beets of 2 or 3 inches in diameter were produced. Those that were planted later than May were usually attacked by a leaf roller, which frequently destroyed all of the foliage. One variety of sugar beets was tried and proved a failure.

Cabbage.—Three varieties were tried in three different plantings. In the first two the seeds were placed directly in the beds in the field and were a failure. The third trial, however, was made with the seeds in a box under shelter, and a good supply of healthy plants was secured. These were transferred to the field, and approximately one-fourth of an acre was set with them. Most of them lived, but made very slow growth and were badly infested by a cabbage worm which perforated the leaves almost as fast as they were formed.

Sweet corn.—Eleven different varieties were tried in eight different plantings, a planting usually being made about every month. Although in some instances the corn was taken from the ground by mice or eaten by ants (which are very fond of anything sweet) before it had time to germinate, we usually succeeded, by replanting and trapping the mice, to get a good stand, and for a very short period the corn usually grew very well. It was very badly infested by a budworm which ate the centers out of the stalks, so that they rarely attained a height of more than 2 or 3 feet. Occasionally a stalk would tassel and form silk, but of all these plantings no ear of corn ever reached the roasting-ear stage.

Cucumbers.—Six different varieties were tried in eight different plantings. These plantings extended from November, 1901, to May, 1902, and in the majority of cases proved to be failures. The young plants were unable to withstand the attacks of a small beetle and a mite, as well as the fungus diseases which prey upon them. A few plants succeeded in reaching a mature age, blossomed quite freely, and bore a number of fruits, some of which attained a size of 6 to 8 inches in length.

Lettuce.—Five different varieties were tried in six different plantings, and as a rule the plants made a fair growth. They were sometimes destroyed by the changa, but no other insect or plant disease seemed to affect the plants. The growth of the lettuce, however, was usually too slow to produce a tender product, and it almost invariably had a bitter taste.

Peas.—Five different varieties of peas were tested in four different plantings. They always came up nicely and grew rapidly for a very short time, when the growth seemed to be suddenly checked. The plants would blossom very early, were very small, and produced a few pods, usually with from 1 to 3 peas in a pod. In some instances the plants would be entirely matured within five weeks from the time the seed was planted.

Sweet Potatoes.—Five different varieties of sweet potatoes were tried, and as a rule they did fairly well. There were a number of plantings made on which fertilizers were tried, and of which report will be made under the head of "Fertilizers."

Irish potatoes.—These were tried at three different times and each time proved an absolute failure on account of bacterial disease which destroyed the entire plant, usually before the period of blossoming.

Radishes.—Six varieties of radishes were tried in five different plantings. Many of them were destroyed by the changa, but a fair stand was usually secured. Without the use of fertilizers they grew very slowly and were tough, but where given a liberal supply of commercial fertilizer they made a good growth and were quite tender, although rather strong to the taste.

Squashes.—Four different varieties were tried in seven different plantings. Of all the cucurbitaceous plants the squash seemed to do best, and where the soil was sufficiently fertile the vines usually made a fair growth and produced fruits of a fair size, which ripened and were of fair quality.

Tomatoes.—Three varieties of tomatoes were tried in four different plantings. It was not at all difficult to produce fine plants which grew well for a short time after being transferred to the field, but in each instance they were attacked by a bacterial disease, or a blight, which swept away the entire field before fruits matured. Pl. XXXII, fig. 3, shows the appearance of the experimental plat just before the

last plants had died, and Pl. XXXIII, fig. 4, shows a portion of a large tomato field about a mile distant, which was affected in the same way. The field last referred to contained 30 acres, all of which was planted to tomatoes. A few crates of very good tomatoes were produced from this field, but I am told that the loss on this enterprise was approximately $5,000. In the case of the experimental field, every effort was made to check the progress of the disease by the application of a Bordeaux mixture, but this seemed to be of no avail, for plants that were sprayed repeatedly every few days seemed to perish as rapidly as those which were untreated. On several occasions specimens of the leaves and stems of the affected plants were collected and sent to the pathologist of the Department in Washington for a careful study of the disease. The results of this investigation have not yet been learned.

Watermelons.—Seven different varieties were tested in eight different plantings. During the early stages of growth the plants were more or less affected by insects and fungi, but a fair percentage of the plants succeeded in growing. The vines made a considerable growth, blossomed, and produced watermelons, many of which were of good size and good flavor. One of the worst enemies, however, was the field rat, which usually succeeded in eating a hole in the melon just before it would ripen, in order to get the seeds.

The tropical vegetables have usually succeeded much better than those from the North and have been more exempt from the attacks of insects and less affected by disease. Most of them require a longer period for maturity, and therefore such as yuca, yautia, malanga, arrowroot, and others were not reported upon, because they had not matured when the grounds at Rio Piedras were abandoned.

Several inquiries have been received as regards the possibilities of growing yuca or cassava for the manufacture of starch, and while the station has thus far no definite data, it may be said that the climatic conditions are favorable, and on sandy soil, with good seed and proper management, the indications are favorable. The experimental plats were badly infested by a bud worm for a time, but the plants recovered from the attack and grew well. Pl. XXXIII, fig. 2, shows a plat eight months after planting.

FIELD AND FORAGE CROPS.

Blue grass was tried at two different times. The first time an ordinary amount of seed was sown, with the result that so few plants were secured that it was practically a failure. In the second trial a very large amount of seed was used on a small area and a perfect stand of grass was secured. During the dry season in February this was watered at frequent intervals in order to keep it growing, and it continued to grow and made a fair stand, although at the time of leaving

FIG. 1.—PORTO RICO STATION—YAUTIA, OR TARO.

FIG. 3.—PORTO RICO STATION—BERMUDA LILIES.

FIG. 2.—PORTO RICO STATION—YUCA, OR CASSAVA.

FIG. 4.—PORTO RICO STATION—DISEASED PART OF 30-ACRE TOMATO FIELD.

Rio Piedras, in September, none of it had yet produced seed. It is a question if it will continue to grow year after year. If it does it will be very important in relation to the production of lawns, as none of the native grasses seem to be well suited to this purpose, and there are practically no lawns to be found anywhere on the island.

Clover.—Alfalfa, alsike, common red, and crimson clovers were tried. All these perished after a few months excepting the alfalfa, which was still living at the time the ground was abandoned in September. Its growth, however, had been rather slow, which might naturally be expected on account of the poor character of the soil. On better soil, and especially in the interior, where the lands are better drained, the indications are that alfalfa may succeed, and if it does it will be an important crop, not only for forage, but also for building up many of the worn-out lands and for holding the soil in place on steep hillsides.

Corn.—Dent corn was tried twice, but did very poorly. It seems to be troubled in much the same way as the sweet corn—by a bud worm which eats out the center of the stalk. Even when not interfered with by the worm the growth is usually slow and the plants tassel prematurely. The native corn, which is a flint variety, did much better, and under the most favorable conditions produced a good yield of merchantable corn. Kafir corn also succeeded quite well and produced an abundance of seed. The stalk, when cut down close to the ground, sent up a second growth of suckers which also produced a crop of seed fully as good as the first. How long this suckering process might continue is a matter for experiment. Pl. XXXII, figs. 1 and 2, shows Kafir corn and native corn when in flower.

Cotton.—This product was planted at two different times, and though the plants were small they produced an abundance of cotton. A certain company which has large interests in the United States has planted cotton every month in the year at a number of places on the island, and its agent informs me that they are convinced that cotton can be very successfully grown. On the basis of their results a company has been formed and arrangements are being made to plant a considerable area of this product. If they succeed it is their purpose to install the necessary machinery for ginning the product.

Oats.—Oats were tried twice and came up very well, and usually produced a fair amount of forage. There were only a few spears, however, that ever produced seed, and these were of a very chaffy character.

Teosinte.—This is a large, rank-growing grass which grows very rapidly and matures seed in about three months. When cut down to the ground it readily grows up again and promises to be a very useful grass for forage.

As will be seen from the table relating to field and forage crops, a number of other kinds were tried, but many of them proved to be failures, and it is doubtful if such as barley, rye, millet, or oats would

succeed anywhere on the island, because they are too far removed from their native habitat. In some instances the failures that are recorded in the table are due to the fact that the seed failed to germinate. This, of course, would not be a true test for the product in question.

FLOWERING BULBS.

Several crates of flowering bulbs were sent to the station by a prominent grower in New Jersey. These consisted largely of Bermuda lilies, together with a small amount of freesia, hyacinths, and narcissus. The lilies were planted on several parts of the experiment station grounds, also on some very sandy soil of the American Fruit Company, in order to test the effect of the different types of soil upon them. Owing to the considerable time that the bulbs remained in the crates before they were received and opportunity was given to plant them, they were in poor condition, and as a result many of them did not grow. Fairly good stand was secured, however, but the plants made a small growth and blossomed much earlier than was expected. The flowers were of good size and very beautiful, there usually being two produced on each stalk. Pl. XXXIII, fig. 3, shows the photographs of a number of these beds just before the close of the flowering period. Had this been taken somewhat earlier it would have shown a much greater number of blossoms.

The amaryllis was from a single bulb which was purchased at a seed house in the States and cost 15 cents. It was found, however, that it is identical with a flower which grows in great abundance throughout the island as a wild plant. Could the bulbs of these wild plants be dug up and sent to the States and sold at this rate it would prove a profitable enterprise.

INSECT ENEMIES.

Insect enemies have been very troublesome and in many instances have been almost wholly responsible for the failure of crops. Vegetables from northern-grown seeds have more frequently yielded to the depredations of insects than have the native ones, but this may be due to the fact that the former are usually not well adapted to the climatic conditions and in their weakened state show the effect of insect attacks more plainly.

Among the more common insects may be mentioned the leaf hopper, which has been very bad on cowpeas and all forms of garden beans. It is a small bug that infests the leaves and sucks their sap. When the plants are disturbed it hops to the ground or to other plants. In the daytime it usually remains on the underside of the leaves and is most numerous on the younger plants. It is therefore difficult to treat with a spray, and being a sap sucker it is impossible to poison it. It was treated to slug shot, whale-oil soap, and kerosene emulsion, and by frequent applications many were destroyed, but there always

remained sufficient of them to continue damaging the beans. Another pest which was noticeable on the cowpeas was a caterpillar which ate the pods.

The May beetle was bad at seasons and the adults ate the leaves of quite a variety of crops, while the larva attacked the roots of many kinds of plants. Bud worms and cabbage worms were very numerous, especially on yucca and cabbage. A leaf roller was particularly destructive to beets and in some cases completely defoliated the beet plats in a few days.

Plant lice were plentiful and preyed upon quite a range of plants. The ants which foster them are always present in overwhelming numbers.

THE CHANGA.

Among the insects of Porto Rico no other is to be compared to the changa, or mole cricket, for general destructiveness or for the wide range of plants that it attacks. So bad were the ravages of this insect that it was early decided to make it a subject of special study. The station entomologist, O. W. Barrett, has given much time to the study of its habits and to trying all sorts of remedial measures for exterminating it. Time enough has not yet elapsed to have completed the study of its life history; neither have the remedies thus far tried been so satisfactory as to warrant discontinuing further investigation with reference to it. Much valuable economic material has been gathered, and in view of the demand for this kind of information by the Porto Rican planters a bulletin in both English and Spanish has been issued, entitled The Changa, or Mole Cricket, in Porto Rico. A cut (fig. 1) of the changa and extracts from the bulletin are here presented:

Since the hurricane of 1876 the mole cricket (*Scapteriscus didactylus*) or "changa," as it is popularly called, has continued to be by far the most serious insect pest that the Porto Rican agriculturist has had to deal with. Its damages to tobacco, cane, and small crops in the island amount to probably more than $100,000 annually. Its habits are well understood by the planters, but there seems as yet to be no definite method of combating it successfully, and an authority states that "nothing appears to be known of its economic status."

FIG. 1.—Changa (*Scapteriscus didactylus* Latr.): Adult from above at left, from side at right (from drawing made in the Division of Entomology).

Though the species of mole cricket common in Porto Rico has been known for many years, it seems that Brunner and Redtenbacher were the first to report it (1892) as inhabiting this island; and although it is known to occur from Uruguay to Florida on the continent, and also in Cuba, Jamaica, Haiti, and St. Vincent in the West Indies, it appears to be more injurious to agriculture in Porto Rico than elsewhere.

DESCRIPTION.

The changa is an insect found throughout the island, living in galleries in the ground. It is about 1¼ inches long in its adult stage; its color is a light brownish fawn, more or less mottled with darker areas above and a uniform brown beneath. Its shape is approximately cylindrical and proportionately longer than that of the true cricket. * * *

The expression of the face has a fancied resemblance to that of a monkey, whence the name "changa," being the popular name in Spanish for a pet monkey. * * *

The first pair of legs are good examples of specialized structure; all the parts are greatly modified and peculiarly adapted to the excavation of burrows or tunnels in the earth. * * * When closely bent, the whole leg has a somewhat elliptical outline and is a model of strength, compactness, and adaptability to purpose. Indeed, with the 4 picks and 10 shovels of its first pair of legs, it is no wonder that the changa can burrow its own length in ordinary soil in the space of half a minute. The second and third pairs of legs are of medium size; they present several short but strong spines, and their feet have three joints each, with a pair of claws which are independently movable. Although not structurally fitted for jumping, the three pairs of legs acting in unison suffice to enable the changa to make clumsy leaps of several times its own length. * * *

The entire surface of the body is covered with a short, sparse, yellowish down, though in adult specimens the head, legs, and wing covers are nearly naked. These minute hairs serve to prevent the surface of the body from becoming wetted by contact with the very wet soil through which the changa sometimes has to burrow; they also, by holding the air, enable the changa to float readily upon the surface of water, and this fact enables it, when washed out of the surface soil into a stream or pool, to escape drowning.

LIFE HISTORY.

As above stated, time enough has not yet elapsed for a study of the changa's complete life history. The eggs are deposited in the enlarged end of a side gallery to the changa's burrow from a few inches to a foot or more beneath the surface of the ground. Each female lays from 50 to 100 eggs, which hatch in about two weeks. The larva or young changa is at first nearly white, but soon takes on a darker color and also a clothing of short hairs. It is very active and can readily jump twenty-five times its own length. It grows slowly and probably requires a year or more to come to maturity.

GENERAL HABITS.

The young changa very seldom leaves the ground unless driven out by water, but the adults are frequently to be seen hurrying over the surface even in the daytime. Their gait is more clumsy and irregular than is the case with most crickets. When greatly excited, they supplement their ordinary gait with short jumps.

The adult males frequently fly at night and are attracted to light. Though their flight is laborious, like that of a large beetle, and not long sustained, they sometimes rise to a light 20 feet or more above the ground. They seem to prefer dark, cloudy nights in which to make their aerial excursions. There are doubtless other conditions which are important regarding the flight of the changa, because of two apparently similar evenings the changa may emerge in great numbers in one, whereas during the other scarcely a single one may be seen. From 7 o'clock until 10 o'clock are the hours preferred for their flights. Thus it does not, as has been stated, fly only at twilight.

The changa is sensitive to humidity. Unless the surface of the soil is moist, it remains at a depth of several inches, and if the soil is saturated it comes to the surface and escapes or remains hidden in grass clumps. Whenever the soil is moist and not too hot, be it night or day, its work of destruction is carried on, though, of course, much the greater amount of damage is done at night. Its habit of burrowing just beneath the surface in a great measure saves it from the attacks of lizards, but not entirely from fowls and blackbirds, that are quick to notice the slightest movement of the earth on top of the burrow and to recognize the cause thereof. These burrows may be traced often for several feet, or even yards, the loosened and raised convex surface plainly indicating the course taken, and at the end of the visible portion of the burrow there may be noted an opening, either the entrance or exit, or else the descent of the burrow. These burrows, ramifying through the soil in the vicinity of food plants, are kept open and utilized for a considerable length of time by all the mole crickets frequenting that soil area. Thus it will be seen a changa can readily pass from the roots of one food plant to those several feet, or perhaps even yards, distant without emerging from the ground or making any new gallery. This fact partially accounts for the great number of small seedling plants which may be destroyed by one or two crickets in a plat of ground in the space of one night. Keeping the earth pressed firmly about the roots of a plant closes the burrows and greatly hinders the changa's operations.

FOOD HABITS.

The changa's food consists almost wholly of living plants. The stomach, however, is always found to contain more or less mud and sand, which is probably unavoidably eaten along with the roots. Portions of decaying plants and the leaves and stems of living plants are sometimes eaten. When food is scarce the leaves and roots of plants, especially those of the "yerba dulce," are drawn into the galleries, sometimes to a distance of a foot or more, there to be consumed at leisure during the daytime. * * *

The usual point of attack on a plant is the crown or junction of stem and roots, but the whole root system and a good part of the stem is frequently devoured. In eating the stem the changa often remains just beneath the surface and pulls down the plant as fast as it is consumed. Thus a plant 4 inches in height in the evening may appear only 1 or 2 inches high the next morning.

Plants having a poisonous or acrid sap are free from attacks. The economic plants most injured by the changa are cane, tobacco, and rice. Among the small crops the tomato, eggplant, turnip, and cabbage are most affected. Very little is known as to the extent of the damage upon the coffee crop; but a considerable percentage of the young seedlings in the nursery beds belonging to the experiment station have been deprived of their taproots. Young seedlings of citrus fruits are frequently attacked, but much of the loss usually attributed to the changa is due to the grubs of the orange-leaf weevil (*Exophthalmus spengleri*), or to those of the smaller May beetle (*Lachnosterna* sp.), or to a peculiar bacterial or fungus disease known locally as "san cocho," which causes the bark of the roots and stems near the soil surface to decay.

Of ornamental plants the coleus seems to be a favorite food. The castor-bean plant, watermelon, bean, sweet potato, cassava, and "yautia" (taro) are seldom or never attacked.

It seems that in its habits of gnawing away a ring of bark from roots and underground parts of stems of some plants and of eating directly into the heart of others the changa shows a sort of mania for killing quite beyond its hunger-satisfying instinct. * * *

INTRODUCTION INTO PORTO RICO.

It is the current belief among the better-informed agriculturists here that the changa first reached Porto Rico in a shipload of guano brought from South America about the year 1850, but since the same species is found throughout tropical America from Uruguay to Florida, it seems probable that the changa was here before the

guano arrived. However, it was not universally considered a serious pest until after the hurricane of 1876, which practically destroyed its worst enemy, the blackbird. For the next few years the changa was so abundant in some localities that they often came to the lights in the houses in such numbers as to literally cover the floors with a loathsome, wriggling mass of their bodies. Since about 1885 their numbers were slightly diminishing until the hurricane of August 8, 1899. It is said by some that they first appeared in the west end of the island and have gradually migrated eastward.

The vicinity of Mayaguez was the first district of the island to suffer from this plague, and it happens that the estate recently purchased by the insular government for the permanent use of the experiment station at Mayaguez, which was formerly known as "La Carmen," was the first estate to abandon the cultivation of cane on account of the ravages of the changa and the cane disease which was believed to always follow the changa's attacks.

CLASSIFICATION.

The following statements regarding classification and distribution, prepared by Mr. Barrett, were omitted from Bulletin No. 2 on account of its technical nature:

The changa belongs to the order Orthoptera, which includes some 30,000 or more species comprised under the heads of cockroaches (Blattidæ), walkingsticks and leaf insects (Phasmidæ), mantids (Mantidæ), crickets (Gryllidæ), grasshoppers (Acridiidæ), and the locusts (Locustidæ). The earwigs (Euplexoptera) were formerly included in this order.

The first Gryllidæ includes the mole cricket (Gryllotalpinæ), the field cricket (Gryllinæ), the tree cricket (Œcanthinæ), and two or three but little known families. The subfamily Gryllotalpinæ includes the true mole crickets (Gryllotalpinæ), and the water mole crickets (Tridactylini). The latter tribe includes the genus Tridactylus—small insects to be observed hopping over stones or sand near water courses; they seldom exceed half an inch in length and resemble a young changa, but have two pairs of stylets at the tip of the abdomen. A species of this genus was sometimes, though rarely, seen at the station grounds at Rio Piedras.

The black mole crickets (Stenopelmatinæ) are wingless, heavy-bodied locusts living under stones and logs; none have been found, to our knowledge, on the island. The black mole cricket of Mexico (*Stenopelmatus talpa*) is usually parasitized by a larval form of hair snake (*Gordius* sp.?); and this parasite serves to keep the species in check in that country.

The tribe Gryllotalalpini comprises some thirty or more species of the genera Gryllotalpa and Scapteriscus, all of which have similar habits and are similar in appearance; the principal differences are in the size, coloring, and hairiness or spininess. They all make subterranean galleries; some remain during the day in more or less permanent retreats beneath stones, issuing at night to forage.

The shrill stridulation which is heard here during every night in the year is produced for the most part by two species of tree crickets, a small species of locust (*Xyphidium fasciatum* De Geer), and the common cricket (*Gryllodes mutucus* De Geer) which sometimes enters houses. The changa's faint note can also be distinguished among these noises when once the ear becomes accustomed to it as a unit.

DISTRIBUTION.

Though found in all the continents, the species of mole crickets are most numerous in tropical America; 15 species are recorded from this district. Five species inhabit the East Indian region and at least 4 are known from the West Indies. Six species are known in the United States, 4 species of which have become established in Florida.

The following is a list of the most important species and their habitats:

Species.	Region inhabited.
Gryllotalpa gryllotalpa L	Europe, W. Asia, N. Africa, Java (?), Isle of Bourbon.
G. unispina Sauss	Turkestan.
G. longipennis De H	Java, Borneo.
G. minuta Burm	Cape of Good Hope.
G. africana Beau	Africa (except north coast), Madagascar, S. Asia, East Indies, Japan.
G. debilis Gerst	Zanzibar.
G. hirsuta Burm	Singapore, Sundas.
G. coarctata Walk	Ceram, Australia.
G. australis Frichs	Ceram(?), New Caledonia, Australia.
G. siamensis Giebel	Farther India.
G. nitidula Serv	Australia.
G. devia Sauss	Cape of Good Hope.
G. chilensis Sauss	Chile.
G. claraziana Sauss	Argentina.
G. hexadactyla Perty	Brazil, Peru, Colombia, Guianas, Costa Rica, Grenada, Mexico, Cuba, St. Vincent, Guadalupe.
G. macilenta Sauss	Surinam.
G. intermedia Sauss	Gulf coast region of Central America and Mexico.
G. cultriger Uhler	El Paso, Tex., to California, U. S. A.
G. major Sauss	Illinois and Kansas, U. S. A.
G. borealis Burm	U. S. A. and Canada east of Rocky Mountains, Mexico(?), Cuba.
Scapteriscus tenuis Scud	Brazil.
S. oxdactylus Perty	Brazil.
S. mexicanus Burm	Brazil, Colombia, Mexico, Florida (U. S. A.)
S. didactylus Latr	Uruguay, S. A., to Florida, U. S. A.; also Cuba, Jamaica, Porto Rico, Haiti, and St. Vincent.
S. vicinus Scud	South and Central Africa.
S. agassizii Scud	Brazil, Central America, Santa Cruz.
S. variegatus Burm	Colombia, Santa Lucia.
S. abbreviatus Scud	Pernambuco (Brazil), Florida, U. S. A.

Besides the two species in the above list which are known to inhabit Porto Rico, it is obvious that *S. agassizii* of Santa Cruz, *S. variegatus* of Santa Lucia, and the two other species of Florida may be expected to appear here at any time; likewise *Gryllotalpa borealis*, *G. cultriger*, and *G. hexadactyla* are liable to be introduced in importations of nursery stock.

It may be interesting to note that a species of mole cricket, said to be the same as the Porto Rican changa, appeared in such numbers in Venezuela several years ago that the cultivation of cane had to be abandoned. We understand, too, that some districts of Africa and Australia are badly infested with the mole cricket. Several districts in Florida have had to be abandoned on account of this pest. And even in Canada the northern mole cricket has been found at the rate of 3,500 per acre in a cabbage patch.[a]

RELATION TO SOIL CONDITIONS.

The mountain districts of the interior are usually more free from the changa than the coast region. This is very largely due to the fact that the mountain soils are clayey, while those of the coast plains and the broad valleys are of an alluvial sandy loam. It is obvious that the changa can not work in clay, on account of its tenacious and noncompressible nature; while in the loose granular structure of the loamy soil the changa readily presses aside the particles of earth and forms a gallery, without excavating or bringing to the surface any of the displaced material.

As previously stated, saturation or overdryness of the soil are conditions avoided by the changa. Prolonged rains in lowlands are probably destructive to many of the young, which have come to the surface to escape drowning; and during a prolonged drought they descend to a considerable depth, and it is possible that in an open field some of the young die from their inability to find food or to migrate, as do the adults, by an overland trip.

We find that the changa evinces an aversion to making a surface burrow up the side of a plant hill or ridge of earth. For this reason single plants should be "hilled up" when practicable.

In sandy cane lands two and sometimes three plantings of the cane are necessary on account of the greater numbers as well as greater destructiveness of the insect in these soils; whereas in a cane soil that carries a high percentage of clay, as in those in the vicinity of Rio Piedras, only about 1 per cent of cane cuttings is destroyed by the changa. These rules hold good also for tobacco, rice, and other crops; the more clayey the soil the less damage can be done by the changa to crops grown therein. There is a difference of opinion among cane planters here as to the method of setting the cane cutting in the soil. Some aver that the cutting has a better chance when planted horizontally, because of the number of roots produced at all the nodes, while others claim that a changa will remain near a cutting until all the tender roots are devoured anyway, and therefore the upright position is better, which gives the continually forming roots a chance to grow and harden beyond the changa-food stage between the brief visits of the changa. But we believe the best plan to avoid the attacks is to lay the cane cutting, with its leaves still attached, upon the soil in a slight depression. Thus, as the young roots start they are touched by the influence of the air and the light, and when they are covered with the hoe, lightly at first and more deeply later, they are too hard for the changa's jaws.

Though our personal observations have not yet extended over an entire year, there is little doubt that the changa's period of greatest activity, as evinced by their com-

[a] James Fletcher, in 22d Ann. Rpt. Ent. Soc. of Ontario, p. 89.

ing to light and by their depredations in fields, is at the end of the rainy season, that is, in October, November, and December.

REMEDIES.

Generally speaking, preventive measures seem more advisable for small crops or limited areas than destructive remedies, with one exception, viz, the use of trap lights.

We may group the prophylactic remedies into two classes—the physical, or those which prevent the attacks of the changa by obstructions, and chemical, or those which prevent the attacks by the use of chemical substances having a repellant odor.

The most common means of preventing the destruction of small plants is by wrapping them in the leaves of the mamey (*Mammea americana*). This method is very common among the tobacco growers of the island. At the time of transplanting, the young plant, with a small quantity of earth, is wrapped in one or two mamey leaves laid lengthwise around the ball of earth; when placed in the soil the leaf forms an impassable barrier, although there is some danger that the changa may hop over the top ring of leaves, or enter at the bottom and thus gain access to the plant itself. We find, however, from our experiments at the station, that the wrapping of the young plant in this manner retards the growth of its root system, and probably in a measure suffocates the roots by preventing the free circulation of air and water in the soil about them. The thickness and gummy sap of the leaf prevents its decay in the soil for from two to six weeks. If carefully placed, however, the leaf or leaves may be drawn from the soil after the plant has attained sufficient size and vitality to enable it to resist the changa's attacks. Sections of banana leaves are also used like those of the mamey. * * *

An improvement upon the mamey-leaf wrapper is the wire-gauze "sleeve." Galvanized-iron wire cloth, having meshes too small to admit the passage of a half-grown changa, is cut into pieces about 6 by 10 inches. These pieces are rolled into cylinders, into which the young plants are set at the time of transplanting. These cylinders have the advantage of lasting for several seasons, of allowing the roots to extend outside the cylinder, and of allowing a thorough ventilation of the soil. These sleeves may be made of various dimensions to suit the kind and size of plant to be protected. It is always necessary to see that the vertical edges overlap a little, so that an entrance can not be forced between them; and it is well to allow the top rim of the cylinder to protrude 1 or 2 inches above the surface of the soil. Their diameter should never be less than 3 inches, except for very small plants, but the length may be 6 to 12 or more inches.

Cheesecloth has been tried as a barrier, but it rots so quickly that the changa soon passes through it. Cheesecloth covers for seed beds have proven effective in keeping the changas out. Mulches of tobacco stems and castor-oil pomace just beneath the surface of the soil have been tried, but are ineffective. Barriers of coal tar are likewise of no avail.

Clean cultivation may be called a physical remedy. The removal of weeds and grass from a cultivated crop necessarily removes a portion of the changa's food plants, and although at first thorough cultivation seems to indirectly incite the changa to even more ferocious depredations, we have found that the adults emigrate from a clean-cultivated field. It is obvious, of course, that the wingless specimens must remain, or else make an overland trip, which is strongly contrary to their instinct. Many of our first experimental plats were completely devastated during the first three or four months of our occupation of the grounds at Rio Piedras, but by keeping down the "yerba dulce" and all the other native food plants of the changa their numbers have rapidly decreased, until at present the only damages are those perpetrated by occasional tramp-like specimens. Moreover, keeping the ground clean around and between the cultivated plants affords a much better opportunity to the insectiverous birds for detecting the changa, so much so that in a clean-

cultivated, open field which is well policed by birds it is almost sure death for a changa to appear above ground, or even to disturb the surface soil in its tunneling operations during the daytime.

Whenever practicable a field should be plowed and kept free from weeds for several weeks prior to planting. This plan not only starves out the pests, but gives the birds a chance to destroy them.

Special search with hoe or spade in badly infested grounds, just after a heavy rain, may sometimes be relied upon to rid a plat of ground of changas. In this way the pests may be kept in control in small areas at a slight expense. * * * The subject of trap lights has attracted considerable attention, especially within the last two or three years, but for some reason their use has never become universal. * * * Our experiments show that the best and cheapest form of trap light is a lantern (the larger the better) suspended above a receptacle partially filled with water to which a little kerosene has been added. The changa is drawn to the light and, striking the chimney of the lantern or lamp, falls into the receptacle beneath. The water in this receptacle gives it stability and the layer of kerosene on top quickly kills the changas by stopping their breathing pores. The cost of running a trap like this is from 1 to 5 cents a night, depending, of course, upon the size of the wick used. * * * Lights placed at the sides of a field should be provided with reflectors to throw all the light into the field. Fortunately there seems to be very few species of beneficial insects caught in the traps here; on the contrary, adults of two species of cutworms, two or three species of the very injurious May beetles (*Lachnosterna* spp.), and the very numerous leaf-hoppers which infest plants of the bean family are caught in considerable numbers in the traps. A chimneyless trap light has proved almost utterly valueless as a changa killer; the flame is smoky, and even a light breeze causes the tin sides to become coated with a deposit of soot, which, of course, destroys their reflecting power.

Among the repellent remedies which have been tried at the station, mention may be made of naphthalin, carbon bisulphid, or "fuma," creosote, creolin, kerosene, and lime. Of these naphthalin has proven the most effective. The flake or white crystalline form, costing 5 or 6 cents a pound, was used in various ways and amounts, and had very little or no deleterious effect on plants. One-half to 1 dram placed in holes 1 to 1½ inches deep and 1 foot apart prevented the passage of the changa. It was necessary to renew the treatment every three to five days in order to keep the ground saturated with the vapor. Carbon bisulphid was more expensive and less effective than the naphthalin. Kerosene repelled the changa so long as the soil retained strong traces of it, but was found injurious to the plants. Creosote, creolin, and lime had practically no repellent action.

Arsenic in its various compounds is found to be the best substance for combating the changa plague; but its use is attended with some difficulties. The best method of applying it seems to be the following: A quantity of "yerba dulce" plants are gathered, and shaken free of dirt, and cut into pieces of an inch or less in length; then white arsenic or Paris green is sprinkled over the chopped pieces of grass, and the whole thoroughly mixed together so that each piece of the grass will contain more or less of the arsenic. This poisoned bait is then put upon or just beneath the surface of the soil in badly infested areas. The changa will come to this bait even when wilted. It is well to lightly cover this poisoned bait, so that fowls will not eat it. A good proportion is one-half ounce of Paris green (or white arsenic) to every quart (liter) of the chopped grass, though of course this formula may be varied considerably. It is well to moisten the grass before sprinkling on the poison, and we believe there is a slight advantage in adding sugar to the water used in wetting the grass. Instead of putting a large quantity of the bait in one place, it is more economical to strew it in lines or narrow rows among the plants near areas where surface burrows are numerous. Death ensues within a very few hours after eating the bait. Since most of the poisoned insects retire to their deepest retreats when

suffering from the effects of the poison and die there, the bodies are not readily found by the ants; but if a specimen chances to die near the surface, a procession of ants will mark the spot within a few hours. Thus the result of this remedy is not readily seen and its efficiency may therefore be doubted by the hasty observer. But the continued use of the remedy can not fail to keep in check, if not fully exterminate, the enemy in the treated area. Pure Paris green is better for the above treatment than the white arsenic, but at present it is not procurable on the island. It can usually be purchased from dealers in agricultural implements for about 20 or 25 cents per pound. The common arsenic, the powdered form of arsenious trioxid, can be purchased at any local drug store, although a physician's permit may be required. Even allowing for a very liberal waste, 5 ounces of arsenic, when used with "yerba dulce," or a similar bait, properly applied and distributed, should be sufficient to kill practically all the changas in 1 acre of ground within one week.

We find that cuttings of coleus stems 3 or 4 inches in length dipped in white arsenic powder and laid upon the surface of the soil is another remedy for the same trouble.

NATURAL ENEMIES.

Unfortunately the changa has few natural enemies in Porto Rico. Its habits of emerging at night, of spending nearly all its time well hidden beneath the surface of the ground, its comparatively large size, and its great strength, activity, and fecundity combine to render it peculiarly exempt from the dangers which beset the lives of most insects. There is a singular lack of ground beetles of the family Carabidæ here. With a greater abundance of these predaceous enemies of plant-eating insects, the early stages of the changa would be passed in less security. The parasitic flies (Tachinidæ) which trouble the lives of many species of insects can obviously never affect the changa. The hair snake (*Gordius aquaticus*) in its third (?) larval stage lives in the abdominal cavity of various species of grasshoppers in the United States, devouring the fatty tissues and finally the viscera. A very large percentage of the black mole crickets (*Stenopelmatus talpa*) of Mexico are similarly eaten piecemeal. But although we have examined hundreds of specimens of both sexes of the changa, we have never found the slightest trace of any internal or external parasites. Moreover, no trace of any fungus disease has been detected on the changa. In the near future we hope to experiment with the fungus which attacks grasshoppers in the Central States. This fungus (*Empusa grylli*) has been successfully used to inoculate individuals, which are then turned loose in the fields, where they carry contagion and death to the noninfected individuals. It is extremely doubtful, however, if this fungus can be inoculated into the changa, on account of the widely different habits of the grasshopper and the mole cricket, as well as the different climatic conditions here.

The red mite (*Trombidium locustarum*), which is so common a parasite on grasshoppers in the United States, does not attack our changa.

Probably the most important natural enemy of the changa is a species of blackbird, called here the "judia" (the jewess), on account of its enlarged upper mandible. This bird hovers about cultivated fields and pastures, and may often be seen darting down from a tree or fence post to the surface of the ground and hopping back to the perch with a changa in its beak. Of course they can accomplish this kind act to the farmers and themselves only when the changa, on account of the condition of the soil and of the weather, is working at or just beneath the surface. Several other species of birds, the "mazambique," the "mirlo," one which happens to have the name of "chango," and others, are also enemies of the changa. These birds frequently take up their residence near cultivated fields and should, of course, be encouraged in this by the farmers, who should see that the law protecting the birds is vigorously enforced.

The common lizard also consumes considerable numbers of the changa, but, of course, it can work only in the daytime; besides, a lizard under 6 inches in length can only with great difficulty manage to swallow an adult changa. They may be noticed

frequently running about in cultivated fields and gardens carrying in their mouths changas which they are unable to swallow, but which they are determined to hold on to as long as possible. Many changas would probably escape from the small-sized lizards were it not for the fact that a large lizard follows the nonethical custom of dispossessing a weaker brother of his prey whenever an occasion offers.

Domestic fowls often learn to follow a plow and pick up the changas and grubs which are turned up with the earth.

It has been suggested that the horned toad of Mexico and southern United States might become an important enemy of the pest, but is extremely doubtful if that desert animal could withstand our humid climate; moreover, its habits are strictly diurnal.

The common toad of the United States, being nocturnal in habit, may prove of some use in intercepting occasional marauding changas, and arrangements have already been made to introduce it into this island.

Combined and intelligent effort toward judicious and persistent application of the remedies as advised in this report will keep the changa under control in Porto Rico.

The changa is justly considered one of the greatest difficulties the Porto Rican agriculturist has to deal with at present, but it is not sufficiently important to prevent the successful cultivation of any tropical product in the island. Indeed, its injuriousness has been frequently overestimated by discouraged planters; it has been blamed for the unprofitableness of various crops in many localities when poverty of the soil, fungus and bacterial diseases, poor agricultural methods, or unfavorable ecological conditions have been the real causes.

SUMMARY.

The changa is a comparatively large insect of the order of Orthoptera; its habits are subterranean and nocturnal; its food consists largely of roots of plants. The female lays her eggs in the galleries underground. The life of an individual is about one year. Its enemies are lizards and birds, but since these are strictly diurnal in habit, the changa suffers comparatively little from them.

The damage to crops in this island by the changa amounts to probably more than $100,000 annually. The crops injured most are cane, tobacco, and rice; a few crops are exempt from attack. The depredations extend over the entire year.

Comparatively little damage is done in clayey soils; moist, sandy loam is preferred. Saturation and extreme dryness of the soils are conditions which prevent the changa's operations.

The old method of protecting the roots of seedling plants with mamey leaves is more or less deleterious to the plants, but the great cheapness of this method commends it to the tobacco grower. The coarse wire-gauze cylinder is recommended for tomatoes and valuable plants.

Clean cultivation, both before and after planting crops, is recommended, because a large portion of the changa's ordinary food is thus cut off. Hilling up is also recommended where practicable. Special search with hoe or spade soon after a rain may be relied upon to some extent in small plats.

Plowing during the winter and spring months will bring to the surface numbers of the eggs or young larvæ, and this exposure to their enemies will result in the death of a large percentage of their number.

Trap lights are recommended for use on nights when the changa is flying in numbers. A dim light is nearly useless. A large lantern having a reflector and set at the edge of a field, or a lantern with no reflector set in the middle of a field, will give best results.

Arsenic or Paris green sprinkled on chopped grass is the best bait. This poison should be distributed in small patches or narrow rows, just beneath the surface of the soil.

Naphthalin placed in the ground about plants serves to repel the changa, but its use is warranted only in small and badly-infested areas.

SOIL CONDITIONS.

Soil management in Porto Rico is an important but most difficult problem. It is not uncommon to hear a casual observer remark that the soils are very fertile. Excepting virgin land and alluvial lands that are occasionally subject to overflow, however, this is far from the truth, if productivity is an index of fertility. It may be that all the elements of plant food are present in sufficient quantity, but, if such is the case, the plants are obviously unable to obtain them. This lack of availability, if it is such, may be attributed to the poor physical conditions which characterize most of the soils of the island. Climatic conditions and lack of good management are responsible for this condition. Freezing, which is so beneficial to soils, never occurs here. The rains are torrential, and therefore compact the soil; furthermore, they are often so frequent and copious that the soil remains saturated for weeks together. These adverse conditions are still further augmented by preventing beneficial biological processes which are essential to profitable plant production. These conditions present a problem in soil management which will include cultivation, manuring, and crop adaptation. Thorough cultivation, as practiced on level lands with moderate rainfall, is out of the question in the mountainous portion of Porto Rico, because such a system would permit the most valuable part of the soil to wash away to the sea as fast as it could be formed. Some happy medium between this and the present state of no cultivation will probably be the solution. That manuring is beneficial is demonstrated by the experiment with fertilizers reported below. Investigations along this line will form a feature of the experiment station work.

FERTILIZER EXPERIMENTS.

The effect of fertilizers upon the yield of sweet potatoes was very marked, as shown by the following table:

Effect of fertilizer upon the yield of sweet potatoes, variety "Martiniqua."

Plat number.	Date of planting.	Date of harvesting.	Kind of fertilizer.				Yield of tubers per acre.
			Acid phosphate.	Muriate of potash.	Nitrate of soda.	Cotton-seed meal.	
			Pounds per acre.	*Pounds per acre.*	*Pounds per acre.*	*Pounds per acre.*	*Pounds per acre.*
61 [a]	Dec. 2	July [b] 7	.....	.....	.....	.....	5,720
112	Dec. 17	June 27	225	113	37	113	12,044
113 [c]	Dec. 24	...do	.....	.....	.....	.....	16,260
114	Dec. 17	July [d] 2	188	188	.....	.....	19,270
115	...do	July [e] 2	225	.....	75	150	15,055
116	...do	July [f] 7	.....	150	75	150	9,763

[a] No fertilizer.
[b] One-third remained and were dug July 23.
[c] Barnyard manure applied at rate of 1,200 wheelbarrow loads per acre.
[d] One-fourth remained and were dug August 9.
[e] Three-fifths remained and were dug August 9.
[f] One-half remained and were dug August 9.

The applications of fertilizer, as will be seen, were very moderate, and the average yield per acre from the treated plats was at the rate of 14,478 pounds, or an increase of 8,758 pounds over the untreated. This increase is at the rate of 153 per cent. Pl. XXXIV, figs. 1 and 2, shows the appearance of the vines of a treated and the untreated plat, respectively.

The plats were very small, 6 by 12 feet, and for this reason the calculated yields per acre are probably somewhat larger than if they had been grown on large plats. The comparison, however, should remain the same. Potash and phosphate seem to have been more effective than the nitrogen, the largest yield being on plat 114, where no nitrogen was applied.

At the time these potatoes were dug the retail price was $1\frac{1}{4}$ to $1\frac{3}{4}$ cents per pound, and on such a basis the wholesale price should have been fully 1 cent per pound. This would give an average net profit of $87.58 per acre in favor of the fertilizer, or somewhat more than ten times its cost.

Another variety of sweet potatoes, of which only two plats were grown, one being manured with commercial fertilizer, showed an increase of over 300 per cent in favor of the treated plat. The soil on which all the field experiments were conducted had most of it apparently been uncultivated for several years and was overgrown by a dense covering of weeds and bananas, most of which had to be cut and removed before the land could be plowed. The growth of vegetation indicated that the soil was probably not lacking in plant food, but the slow growth of all the planted crops showed that the soil was much impoverished. When the soil was found to be so very poor, investigations were directed along this line. The soil was found to be acid, and air-slaked lime was applied to considerable of it at the rate of 1,000 pounds per acre, either as a top-dressing or raked in. This was in February, at the beginning of the dry season, and consequently the lime laid inert and without effect until the rains set in during the last half of April. During this period moderate applications of commercial fertilizers and barnyard manure were applied to many of the plats, and after the April rains began there was a noticeable improvement in the crops that were on treated soil. The time until the grounds were abandoned for the permanent location, however, was too short for differences in yields to be ascertained.

TROPICAL FRUITS.

A considerable number of tropical fruits grow almost spontaneously throughout the island. (Pl. XXXV, figs. 1, 2, and 3.) They receive no care or cultivation, and it is not strange, therefore, that many of them fall below the standard. The exports of fruits from the island

FIG. 1.—PORTO RICO STATION—SWEET POTATOES TREATED WITH COMMERCIAL FERTILIZERS.

FIG. 2.—PORTO RICO STATION—SWEET POTATOES UNTREATED.

FIG. 1.—PORTO RICO STATION—FRUITS AND LEAVES; TWO VARIETIES OF MANGOES.

FIG. 3.—PORTO RICO STATION—FRUIT AND LEAVES OF THE BREAD FRUIT.

FIG. 2.—PORTO RICO STATION—FRUITS AND LEAVES OF THE SOUR SOP.

FIG. 4.—PORTO RICO STATION—STATION BUILDING AT RIO PIEDRAS.

cut practically no figure in the total exports, for they usually do not exceed one-tenth of 1 per cent of the total. With a climate equally as good as that of Jamaica or Costa Rica and a commercial position superior to them, why should not the growing of tropical fruits succeed?

Quite a number of individuals and several companies have recently engaged in the growing of citrus fruits, but as there are no commercial orchards on the island the possibilities are unknown. There is nothing to demonstrate what varieties of improved oranges may succeed best, what kind of treatment will be required, or what will be the cost of production. Some of the planters will undoubtedly make mistakes, and there is a demand for investigations along this line, which the station should supply. To supply this, however, will require the time necessary to bring orchards into bearing.

It is the purpose of the station to give prominence to the production of various kinds of tropical fruits. Arrangements have already been made for securing different varieties of these from various sources. A banana plantation has already been started, and nurseries of citrus fruits, mangoes, aguacates, and other sorts are now being started at Mayaguez. It is the intention to attempt the improvement of the fruits now being grown on the island by cultivation, cross breeding, grafting, and whatever methods give promise of good results.

FORESTRY RESERVATION.

Only a few remnants of the beautiful tropical forest with which Porto Rico is said to have once been clothed now remain. These remnants are practically all on Government lands and are constantly being robbed of their choicest trees. It has seemed advisable that a part of this Government forest land be set aside for a forest reserve, and the experiment station has, therefore, designated the tract of land most desirable for the purpose. This embraces somewhat more than 25,000 acres and, so far as could be ascertained, was all Government land. It is situated in the northeast part of the island, about Loquillo, and is the most elevated and rugged part. The annual rainfall there is about 150 inches, which, together with the rough character of the district, makes the land of very little agricultural value. Furthermore, the destruction of the forest endangers the farming lands below by subjecting them to frequent overflow. It seems very desirable, therefore, that no further destruction of the forest be permitted, and that this parcel be set aside as a forest reserve. A description and map, prepared by Mr. O. W. Barrett, of the station, were submitted to the proper authorities regarding such a reservation.[a]

[a] On January 17, 1903, the President issued a proclamation establishing the reservation under the name of The Loquillo Forest Reserve.

HERBARIUM AND INSECT COLLECTION.

An herbarium has been commenced and consists of about 300 species of the more economic plants, most of which are in duplicate, and a part of which are in triplicate, the object being to furnish the extras in exchange or give them to other institutions in lieu of their making the determinations. A considerable collection of the native woods of the island has also been brought together and is being prepared for exhibition purposes.

A collection of economic insects has also been commenced, and both this and the herbarium will be increased from time to time until they represent the flora and insect life of the island.

METEROLOGICAL OBSERVATIONS.

Immediately upon beginning experimental work at Rio Piedras a rain gauge was secured from the Weather Bureau and a record of the precipitation was kept, together with observations on the character and direction of the wind, the time of rains, and the character of each day as regards sunshine and clouds. Previously no such record had been kept at Rio Piedras, and as the Weather Bureau desired to continue the record the gauge was transferred to Dr. Todd, director of the insular normal school. As soon as the station became settled at Mayaguez the instruments in the care of the voluntary observer there were transferred to the station, and it will continue the observations, which will include maximum and minimum temperatures as well as rainfall.

Following is a table giving the monthly rainfall at each of four places since the establishment of the United States Weather Bureau in the West Indies. These include the latest available data, and being at the east and west ends of the island, as well as the north and south sides, they show the extreme variation in rainfall to which the island is subject.

Rainfall (inches) in Porto Rico, as recorded by the United States Weather Bureau, January, 1899, to December, 1902.

Locality.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Hacienda Perla:													
1899	7.19	3.98	6.51	18.78	6.72	11.47	10.55	9.92	15.43	16.53	28.13	4.92	140.06
1900	12.05	3.67	4.43	23.34	18.70	18.55	11.04	11.95	15.30	15.83	8.36	8.70	151.92
1901	6.07	1.85	11.03	7.05	16.26	25.34	33.58	8.19	16.10	14.16	16.43	11.67	167.73
1902	13.99	.24	7.25	9.94	19.83	32.92	10.08	8.13	10.06	6.06	.....	.....	.....
Mean	9.82	2.44	7.30	14.78	15.38	22.07	16.31	9.55	14.22	13.14	.....	.....	.....
San Juan:													
1899	2.92	.80	2.29	6.09	2.59	7.23	7.53	10.38	13.66	10.21	11.81	2.10	77.61
1900	3.93	2.13	1.57	5.92	3.83	7.53	6.33	7.00	3.05	8.11	4.50	2.39	56.29
1901	4.36	.50	4.60	.66	4.84	7.05	10.98	8.59	7.39	8.30	9.55	8.43	85.25
1902	12.45	.09	4.08	6.09	13.97	12.22	4.61	4.66	4.85	3.13	.....	.....	.....
Mean	5.91	.88	3.12	4.69	6.31	8.51	7.36	7.66	7.24	7.44	.....	.....	.....

Rainfall (inches) in Porto Rico, as recorded by the United States Weather Bureau, January, 1899, to December, 1902—Continued.

Locality.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Mayaguez:													
1899	.....	.....	.....	.....	.....	.....	14.41	19.02	.....	8.73	3.52	1.04	.....
1900	1.49	1.06	1.21	5.44	6.14	14.03	13.11	14.02	7.44	12.47	2.99	4.20	83.57
1901	2.19	.58	5.72	.58	11.87	10.44	17.06	9.86	13.00	11.27	12.84	2.08	97.49
1902	4.67	.39	.13	10.85	16.56	8.33	7.62	5.80	7.60	5.82	.....	.....	.....
Mean	2.09	.51	1.76	4.22	8.64	8.20	13.05	12.17	7.01	9.57	.....	.....	.....
Hacienda Armistad:													
1900	4.25	.80	1.00	1.10	2.80	16.30	5.50	2.20	4.80	4.46	3.83	4.22	51.26
1901	2.60	1.14	2.63	.32	6.30	4.84	.....	6.03	7.97	6.30	13.97	3.10	55.20
1902	.....	.....	.....	5.41	7.91	7.19	1.73	2.40	2.28	3.19	.....	.....	.....
Mean	2.28	.65	1.21	2.28	5.67	9.44	.....	3.54	5.02	4.65	.....	.....	.....

PUBLICATIONS.

The publications issued by the station are Bulletin No. 1, on the Establishment, Location, and Purpose of the Experiment Station, and Bulletin No. 2, on the Changa, or Mole Cricket, in Porto Rico. These have been printed in both Spanish and English. Bulletin No. 1 gives a brief account of the establishment of the station, describes the farm that has been purchased for it by the insular authorities, and states what the equipment consists of. It also discusses the investigations already undertaken, as well as those that are contemplated, and announces the objects and purposes of the station.

Extracts from Bulletin No. 2 are made on preceding pages, sufficient in scope to give a clear idea of the matter contained in it.

It is the intention to issue two more bulletins in the near future, one on the soil survey and the other giving practical suggestions to coffee planters.

For a description of the island and a discussion of its climate, soils, agricultural conditions, products, and possibilities, the reader is referred to the annual report for 1901.